Chapter 8
Exposed Aggregate Architectural Surfaces

8-1. Aggregate Distribution Methods

a. Mixture proportions. This aggregate distribution method depends on random dispersion of aggregate at the surface of concrete placed either horizontally or vertically into forms. The quantity of coarse aggregate exposed is determined by the proportioning of the concrete mixture. This can vary from the ordinary paving or structural mixture to one designed with a gap-grading and a preponderance of coarse aggregate.

b. Aggregate transfer. The aggregate transfer method of distribution is rarely used due to labor costs, but remains the best means of producing distinctive patterns and sculptured effects with special aggregates. The pattern is laid out on a thin 6.3-mm (1/4-in.) plywood panel and adhesive is applied. This is followed by a layer of aggregate arranged in the desired pattern and entirely covering the liner panel. Some vibration is provided in the horizontal direction. The panel is fastened to the forms with finish nails after the adhesive has hardened. Removal occurs when the concrete is a minimum of 5 days old, dependent on curing temperatures. Use of an adhesive mix containing 50 percent perlite will allow greater reveals. Final cleaning of the aggregates is needed.

c. Preplaced aggregate. The preplaced aggregate method of distribution has aggregate prepositioned in the forms. The voids are then filled with a structural quality grout by high-frequency vibration or pressure. The advantage of this method is a resulting uniform density of exposed aggregate upon completion. These projects usually contain one size of large aggregate particles and are limited to a minimum 254- to 305-mm (10- to 12-in.)-thick section. Exposure of the aggregate is similar to other methods.

d. Aggregate seeding. The aggregate seeding method of distribution is used for placing aggregate in precast and cast-in-place flatwork. The process involves leaving a level surface of concrete 3.2 mm to 11.1 mm (1/8 in. to 7/16 in.) below the finish elevation to allow for the volume of aggregate to be seeded. This depth is approximately one third the depth of the aggregate size. The aggregate is spread carefully by shovel or hand so as to completely cover the surface. Embedment with a wood float, 2 by 4, or roller continues until the aggregate is well tamped into the plastic concrete. Final tamping with a magnesium type of float continues until the aggregate is completely surrounded and covered by the mortar. Upon completion of the tamping, the slab has the look of a normal slab. A surface retarder may be used for large areas to allow time for seeding small size aggregate. When the mortar has set sufficiently to hold the aggregate, the aggregate is exposed by washing and brushing with water.

e. Sand embedment. To achieve a uniform distribution on the bottom of a precast panel which requires an exposed aggregate finish on both sides, a process similar to seeding, known as sand embedment, is used. This involves placing a layer of fine sand in the bottom of the form to a depth of one third the maximum size of the aggregate to be exposed. The aggregate is spread similar to seeding and pressed into the sand. A fine spray of water is used to consolidate the sand and leave one half to two thirds of each aggregate particle exposed. Another method is to place the aggregate in the bottom of the form and then sift the sand over the aggregate until each particle is covered one half to one third of its diameter. Any excess sand is pushed down around the rock with a soft bristled brush and compressed air. Again, a fine spray of water is used to consolidate the sand around the aggregate. Placement of concrete must not displace the sand or aggregate. After form removal, the sand is cleaned off with compressed air, water spray, and brushing. In some cases, a retarder in the sand has been successful in easing this removal. As some of the sand may adhere, its color should be similar to the decorative aggregate.

8-2. Aggregate Exposure Methods

a. Water brush. Exposure of aggregate by water brushing is the general method of exposing aggregate in precast and cast-in-place flatwork. This method does not cause a change in the aggregate original color and texture as it involves the mechanical removal of the mortar by brushing with the assistance of water to soften and dilute the surface mortar. Exposure of the aggregate should not begin until the concrete mortar matrix is sufficiently hard enough to retain the aggregate but still soft enough for removal. Forming for cast-in-place vertical surfaces should be removed within 4 hr, dependent on hydration temperatures, to allow exposure by water brushing. Surface retarders will allow more leeway in form removals, but require strict supervision to ensure uniformity. When early form removal cannot be accomplished, aggregate on vertical surfaces can be exposed by sandblasting. Residual mortar from water brushing may be cleaned off with a mild muriatic acid wash.

b. Surface retarders. In order to ease the exposure of decorative aggregate in architectural concrete, retarders are used to delay the hardening of the surface mortar on horizontal and vertical surfaces.

(1) Horizontal surfaces. On precast or cast-in-place flatwork, exposure time is extended to allow seeding of large panels or during hot weather. While the surface mortar is soft, exposure of aggregate can easily be accomplished by washing, sandblasting, or brushing. This method has been very successful on the upper surfaces of horizontally cast panels such as tilt-ups and is used extensively by the precast plants to hold aggregate color change to a minimum.

(2) Cast-in-place vertical surfaces. Many projects have had retarders applied to vertical forms for cast-in-place architectural concrete with varied success. Acceptable results require rigid control of timing and thickness of retarder application, form removal, and aggregate exposure. Temperatures, rain, and placement of concrete affect the retarder on the form and its result on the concrete surface. The result of nonuniform retarder action on a cast-in-place vertical surface is illustrated in Figure 8-1. Attempts to control all these items are difficult on a tall column or wall. Most recommendations restrict this method of exposure to small areas of cast-in-place concrete, where placement of the concrete can be carefully controlled to prevent wiping off the retarder, timing of form removal is approximately the same, and the exposure times are the same. Any proposed use of a form retarder should be tried in the field on the mockup providing equivalent timing or an available nonarchitectural wall surface prior to the production of project architectural concrete. In some cases the retarder has not been compatible with admixtures used in the concrete mixture.

c. Acid etch. An acid etch is used by precast plants to produce a fine texture with application of 5-percent to 35-percent hydrochloric acid. The application is made by spray, brush or immersion of the unit. Acid-resistant aggregates siliceous in nature, such as quartz or granite, should be used. Dolomite or marble aggregates of a carbonate nature can be discolored or seriously damaged by the acid. After acid etching, the unit must be neutralized with an alkaline bath and thoroughly flushed with water. Safety clothing must be worn by workers to avoid acid burns. Acid etching should not be attempted until the concrete is 14 days old or has a compressive strength of 31 MPA (4,500 psi).

d. Acid wash. An acid wash is used to clean exposed aggregate surfaces after the surfaces have been exposed by other means. It is also used to restore luster and color after exposure to contaminants.

e. *High pressure water jet*. A recent development has been to use high pressure water jets to expose aggregates. Such water jets have pressures varying from 21 to 69 MPA (3,000 to 10,000 psi) and may include up to 10 percent sand in suspension for abrasion assistance.

f. Sandblasting. A common method of exposing aggregate in vertical cast-in-place concrete walls is sandblasting. Uniformity of appearance requires uniform density of the surface. Use of high-density forming is recommended for this purpose and should be required by the specifications. Where only one use of the forming is expected, medium density forming has been satisfactory.

(1) Equipment and abrasive materials. Satisfactory sandblasting equipment should furnish a minimum of 8.5 m^3 (300 ft^3) per minute of air per nozzle and a minimum air pressure of 620-690 kPA (90-100 psi). In order to keep the maximum amount of abrasive material in suspension, the air hose should have a minimum diameter of 37.5 mm (1-1/2 in.). Abrasive materials for blasting range from silica sand to abrasive grits for deep cuts. Due to environmental restrictions, many cities require that sand used for sandblasting purposes contain approximately 6 percent moisture to minimize dust. The resulting residual film of abraded material may require cleaning by additional dry sandblasting or flushing with a water spray. For

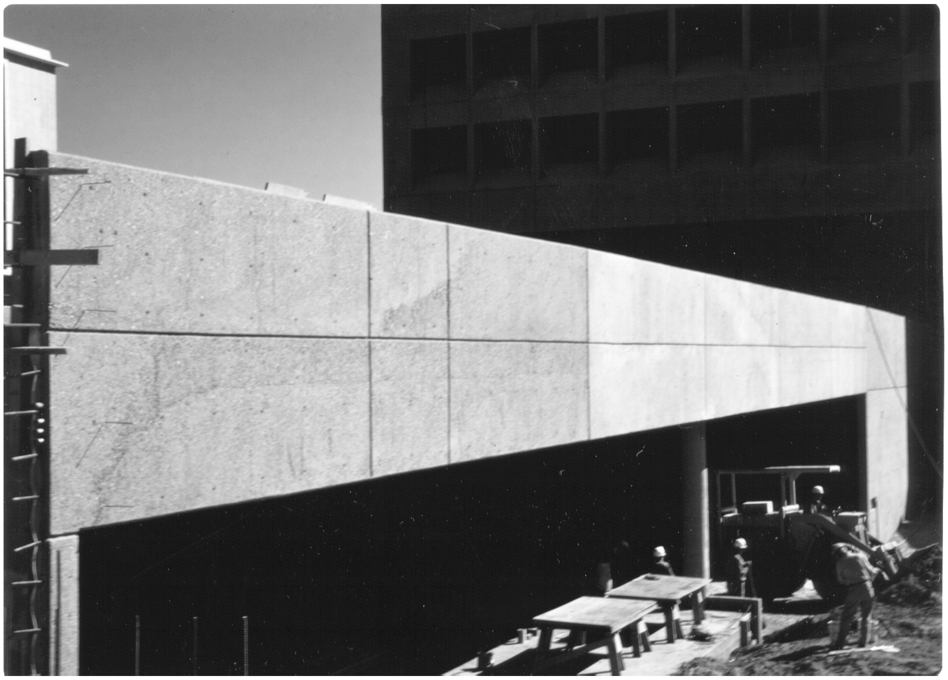

Figure 8-1. Result of nonuniform retarder action

white and light cement concretes, abrasive materials should be checked for color contamination. Blasting should be done with the nozzle perpendicular to the surface and about 0.6 m (2 ft) away. The actual distance will depend on air pressure, hardness of the concrete, and the cutting rate of the abrasive.

(2) Grades. ACI Committee Report 303 (ACI 1974) developed four grades of sandblasting for use by the concrete construction industry which should be used for planning, design, and construction. The grades are based on amount of reveal, which is defined as the amount of projection of the aggregate out of the concrete matrix. Visual examples of the four grades can be seen in Figures 8-2, 8-3, and 8-4. The grades are defined as:

(a) Brush. No reveal is expected. Purpose is to remove sheen due to high-density forming. May not be sufficient to produce uniform color.

(b) Light. Maximum reveal 1.6 mm (1/16 in.). Exposure of occasional coarse aggregate acceptable but not mandatory. Resulting color expected to be uniform.

(c) Medium. Maximum reveal 6.4 mm (1/4 in.). Exposure of coarse aggregate expected to predominate.

(d) Heavy. Maximum reveal 12.7 mm (1/2 in.) or 1/3 diameter of coarse aggregate. Surface to be mostly rock.

Proper time of sandblasting varies with the grade specified, economics, and the construction schedule. Concrete strengths should be above 13.8 MPA (2,000 psi). Brush and light sandblasting can be done at the convenience of the construction schedule, except that all sandblasting should be done at the same age. A caution is given that brush and light grades require excellent concrete as they accentuate any defects such as bugholes, lift lines, form leakage areas, cracks, and rock pockets. As the depth of sandblasting increases to medium and heavy, the randomness of the rock size, distribution, and color begin to dominate the overall appearance and the contrast of any deficiencies diminishes. It is more economical and less abrasion results on the aggregate if sandblasting is begun within 24 to 72 hr after placement for the medium and heavy grades. As the concrete ages, the matrix abrasion

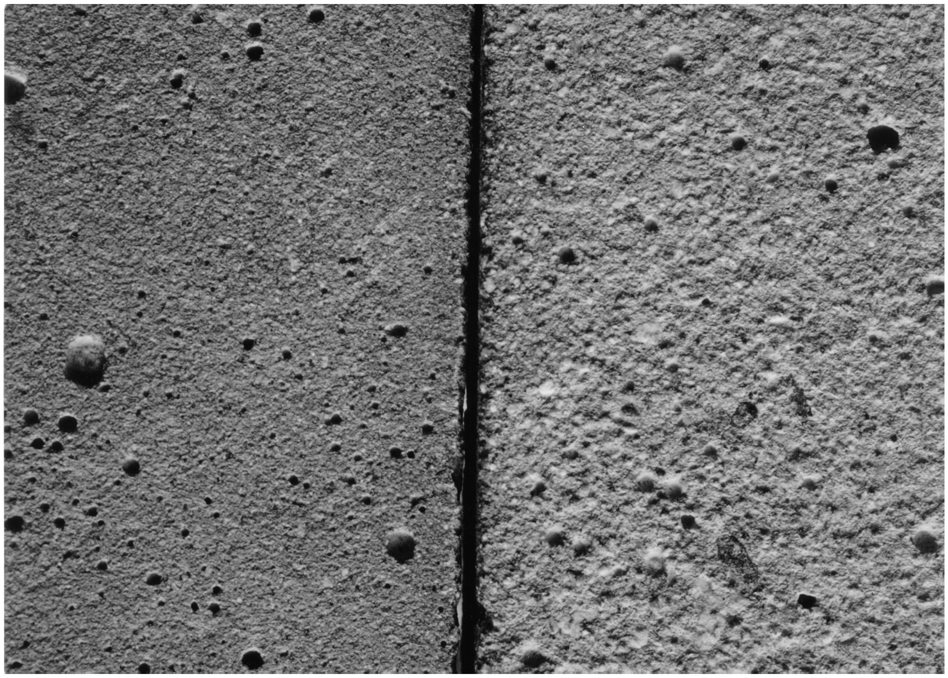

Figure 8-2. Examples of sandblasting grades: brush on left and light on right

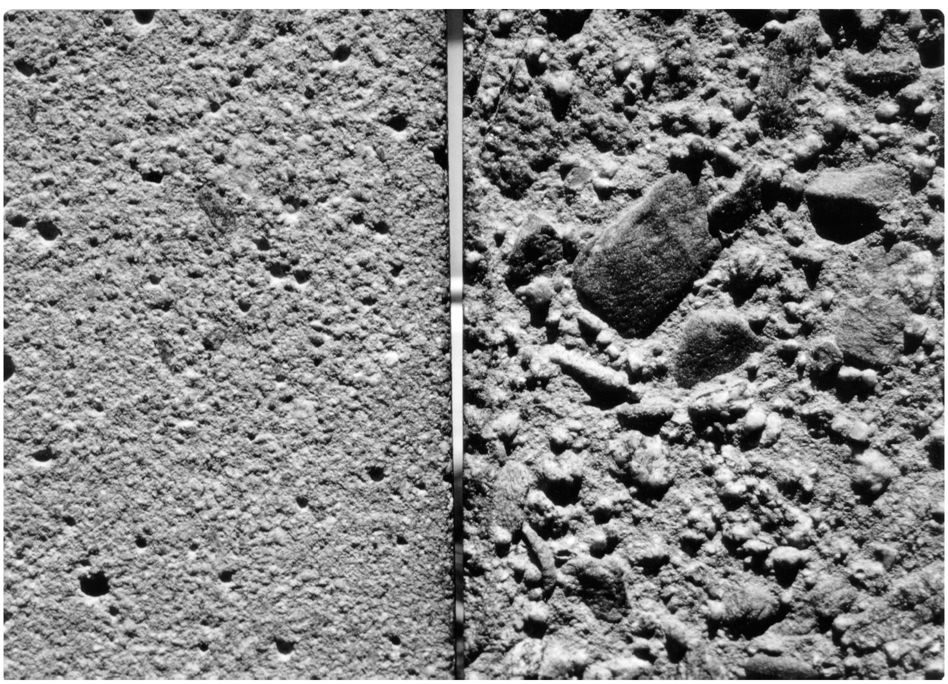

Figure 8-3. Light sandblast on left, medium sandblast on right

resistance begins to approach or exceed that of the aggregate. In order to achieve the same reveal, lightening and flattening of the aggregate are increased. All aggregates exposed by sandblasting will tend to be lighter than the original color. Prior to any sandblasting operations, proposed methods and materials should be tried on the field mockup to determine if the completed product meets the architectural and cover requirements.

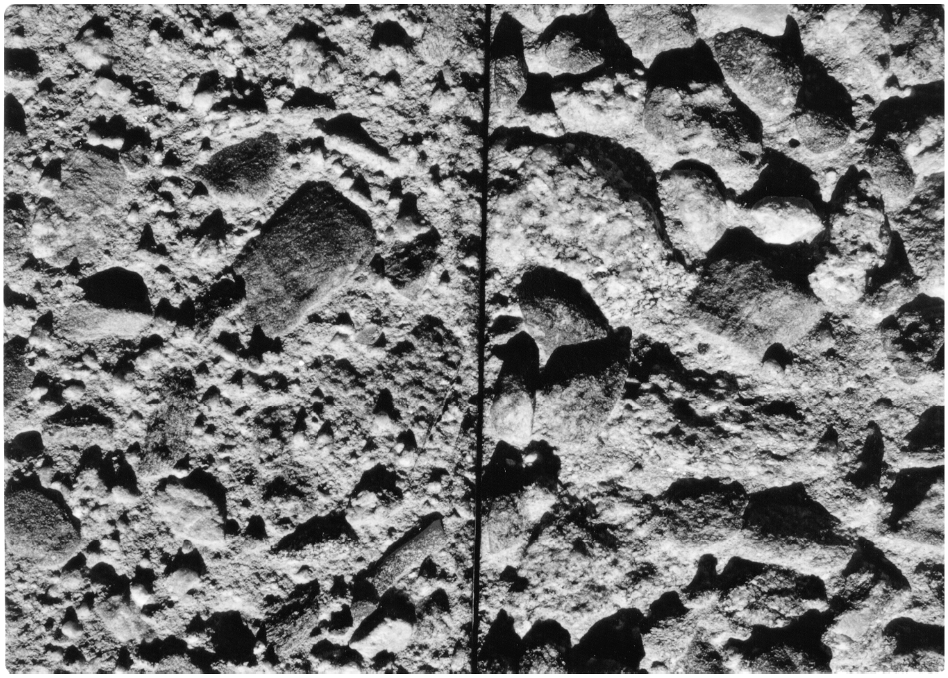

Figure 8-4. Heavy on left, medium on right

If not, changes should be made and another field mockup completed. Final production concrete should not be attempted until a satisfactory field mockup sample is obtained.

g. *Bush hammering*. Bush hammering exposes the aggregate by fracturing the surface of the concrete through impact of a pneumatically driven tool with steel teeth. Shape of the tool varies from square to rectangular or cylindrical. Typical tools for obtaining bushhammered concrete surfaces can be seen in Figure 8-5. For large areas, a jig composed of a number of bush hammer tools is used. The resulting surface is rugged and uneven, with the surface mortar removed. All of the visible coarse aggregates should have the exterior shell removed. As all of the exposed aggregates have been shattered and the interior exposed, the original color of aggregate remains. Characteristics of a bush-hammered surface are shown in Figure 8-6. A sealer will darken the surface but also brighten the aggregate color. The minimum strength and age of the concrete for bush hammering should be 27.6 MPA (4,000 psi) and 14 days. A more uniform appearance will be obtained if bush hammering is delayed until the concrete is 21 days old and has had a period of drying. To prevent breaking off corners, chamfers should be used on corners or the bush hammering kept back 63 mm (2-1/2 in.) from any corner. As approximately 10 mm (3/8 in.) is removed by bush hammering, additional cover will be required to maintain minimum cover of reinforcing.

h. *Grinding*. Grinding results in a smooth exposed aggregate surface. The process requires more labor than any other type of aggregate exposure. Overhead and vertical surfaces are extremely difficult. A few precast plants have developed the process further and produce honed panels which are highly polished. With certain aggregates and colored or white concrete, the resulting product resembles natural polished stone.

i. *Fractured rib*. The fractured rib texture requires an as-cast ribbed finish initially. The ribs are then broken laterally, either manually with a hammer orwith a mechanical tool. If the blows are from alternate directions, the result is a rugged type of texture with broken aggregate visible in the fractured rib. Trial fracturing of ribs should be made to train personnel and determine proper timing for adequate bond strength to ensure fracturing of the aggregate. Figure 8-7 illustrates the development of a fractured rib texture.

Figure 8-5. Tool used for bush hammering concrete surface

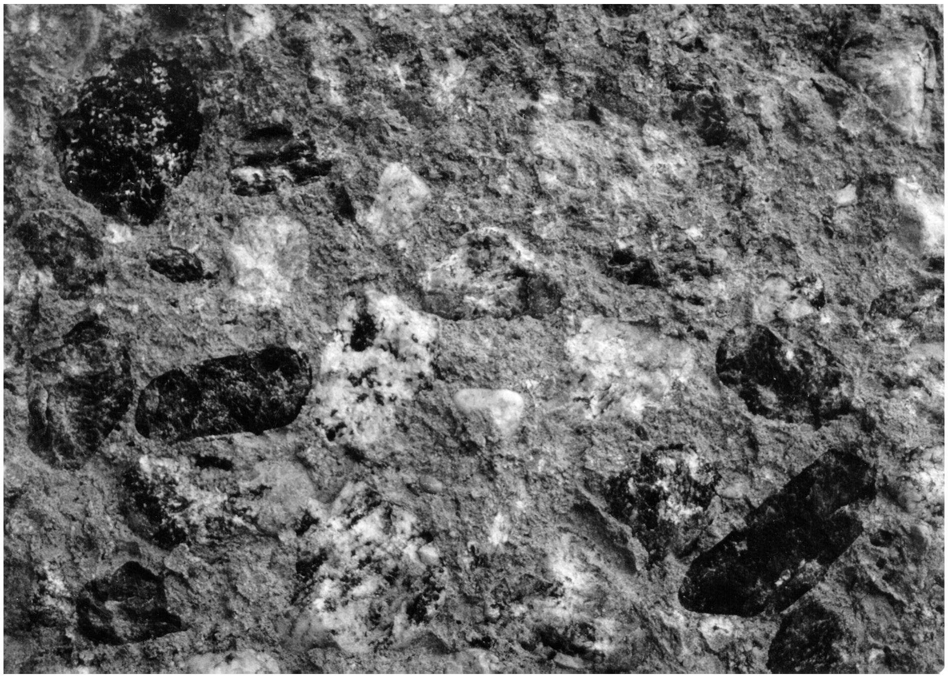

Figure 8-6. Bush-hammered surface

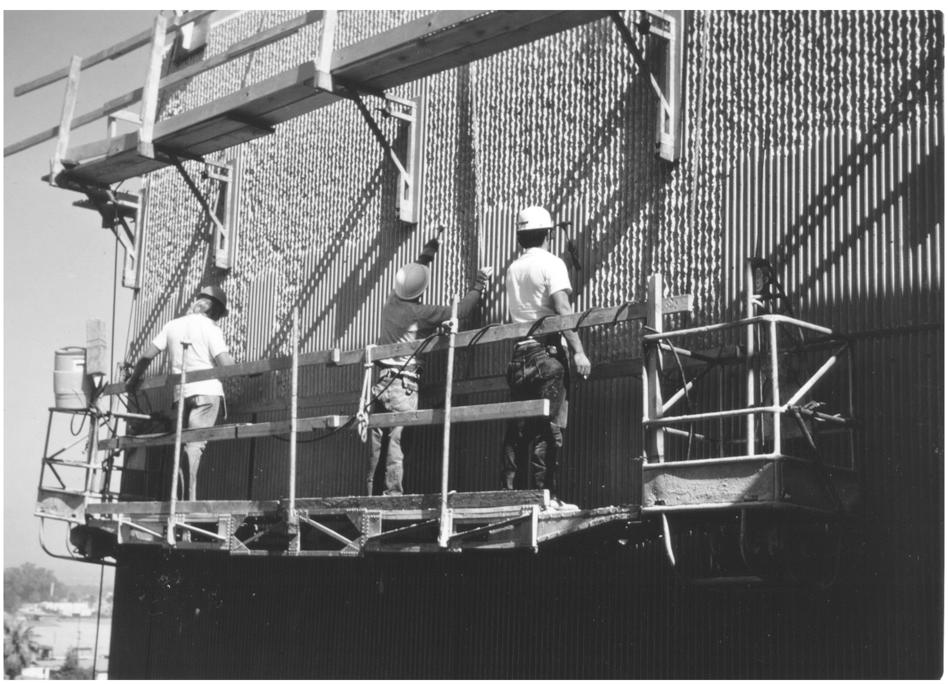

Figure 8-7. Fractured rib texture being developed